Angular distributions of the protons in the reaction $\pi^+ + Xe \to p + \cdots$ at 2.34 GeV/*c* as a background for the shock-wave effect

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Results are presented of an analysis of the angular distributions of protons with $E_p \geq 30$ MeV emitted with different numbers of secondary charged particles in $\pi^+ + Xe$ interactions at 2.34 GeV/*c*. The obtained distributions are compared with the analogous characteristics of the protons emitted in collisions of protons or α particles with heavy emulsion nuclei and with lead at 70 and 17 GeV/*c* (O. Akhrorov *et al.*, JINR R1-9963, Dubna, 1976). It is concluded that the investigated distributions reveal no irregularities capable of attesting to a noticable role of the shock-wave mechanism in the target nuclei.

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The possibility of formation of a shock wave in nuclear matter has begun to attract attention recently as a model of target-nucleus fragmentation via interaction between fast hadrons and atomic nuclei.[1] Although this hypothesis encounters many objections, the available experimental data are quite fragmentary and do not lead to a definite, affirmative or negative, answer to this question. The possibility of verifying the shock-wave model by comparing the characteristics of the protons emitted in interactions of different particles at different energies has been mentioned in[2] It is known that pions with energy ~ 2 GeV are much less likely to produce a shock wave than, say, α particles, but the mechanism of preequilibrium emission of particles[3] should play a noticeable role in this case.[2] Consequently, a comparison of the angular distributions of the protons emitted in collisions between pions and sufficiently heavy nuclei, on the one hand, with the analogous distributions of the protons accompanying the collisions of relativistic nuclei with medium and heavy nuclei, on the other, is of interest from the point of view of assessing the validity of the shock-wave model.

We present here the results of an investigation of the angular distributions of protons of energy $E_p \geq 30$ MeV, emitted in $\pi^+ + Xe \to p + \cdots$ interactions at 2.34 GeV/*c*. The experiment was performed with photographs obtained with the 26-liter xenon bubble chamber (XBC) of JINR.

Description of experiment

We used the results of an analysis of previously obtained 65 thousand XBC stereophotographs.[4,5] We investigated $\pi^{+}+Xe$ collisions at 2.34 GeV/c, leading to emission of an arbitrary number N_{ch} of secondary charged particles. They are designated as follows:

$$\pi^{+} + Xe \rightarrow N_{ch}. \qquad (1)$$

The number of these events was 459. In addition, we selected 2539 events accompanied by emission of not more than 4 secondary charged particles. These events are designated in the following manner:

$$\pi^{+} + Xe \rightarrow (N_{ch} \leqslant 4). \qquad (2)$$

In events of type (1) and (2), we measured the emission angles θ_p and the ranges of the secondary charged particles stopped in the chamber without visible tracks of decays and secondary interactions. It was assumed that these tracks belonged to protons, the numbers of which in the interval $E_p \geq 30$ MeV turned out to be 990 and 1900 events of type (1) and (2), respectively. The error in the measurement of the emission angles does not exceed 5°. The accuracy with which the proton energy was determined is $\sim 10\%$ at $E_p \approx 30$ MeV and $\sim 1\%$ at $E_p = 160$ MeV. Procedural problems were described by us in greater detail in[4].

Experimental data and discussion

Figure 1 shows the angular distributions of protons of energy $E_p > 30$ MeV for the three intervals $N_{ch} \leq 4$, $N_{ch} = 4-7$, and $N_{ch} \geq 8$. The distribution corresponding to the interval $N_{ch} \leq 4$ is represented by events of type (1), while only events of type (2) participate in the remaining distributions ($N_{ch} = 4-7$ and $N_{ch} \geq 8$). The histograms are normalized to each other. If it is recognized that $\pi^{+}+Xe$ interactions with large numbers N_{ch} of secondary charged particles

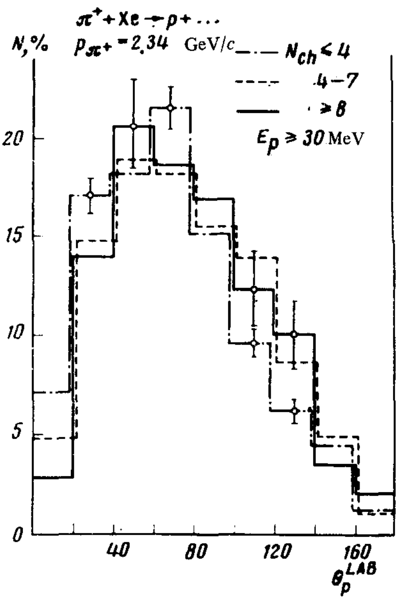

FIG. 1. Angular distributions of protons with $E_p \geq 30$ MeV, emitted in $\pi^{+}+Xe$ interactions with various numbers N_{ch} of secondary charged particles at 2.34 GeV/c. The histograms are normalized to each other.

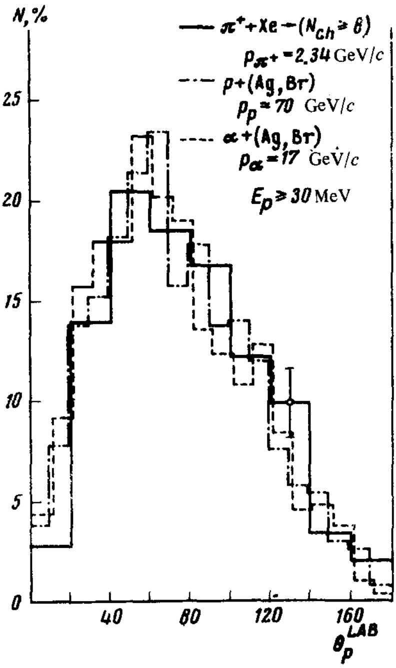

FIG. 2. Angular distributions of protons with $E_p \gtrsim 30$ MeV accompanying the following: $\pi^+ + \mathrm{Xe}$ interactions with $N_{ch} \gtrsim 8$ charged particles at 2.34 GeV (solid); central interactions of protons with heavy nuclei of emulsion and Pb nuclei at 70 GeV/c (dash—dot); central collisions of α particles with heavy emulsion nuclei and lead nuclei at 70 GeV/c[7] (dashed). The histograms are normalized to each other.

correspond qualitatively to more central collisions (in the sense of the impact parameter), then conditions for the formation of a shock-wave front are most favorable in the class of events $N_{ch} \gtrsim 8$. Consequently, if the shock-wave mechanism plays a noticeable role in the investigated reaction, then the angular distributions of the protons emitted in interactions with $N_{ch} \gtrsim 8$ should exceed the distributions corresponding to smaller N_{ch}, in the region of $\cos\theta_p \approx 0.2$, i.e., $\theta_p \approx 80°$ (e.g., [2]). The absence of such a difference, at the attained experimental accuracy, might mean that the discussed mechanism of emission of intermediate-energy protons ($E_p \gtrsim 30$ MeV) in $\pi^+ + \mathrm{Xe}$ collisions at 2.34 GeV/c does not manifest itself at the level 30—40 mb, which amounts to approximately 3% of the total cross section of the inelastic processes.[6]

It is of interest to compare the obtained angular distributions with the corresponding distributions of protons with $E_p \gtrsim 30$ MeV emitted in collisions of 70-GeV/c protons and 17-GeV/c α particles with heavy emulsion nuclei (Ag, Br, and Pb) under the conditions of the so called total disintegration of the target nucleus.[7] In this case, too, central collisions take place and the conditions are most favorable for the onset of a shock wave. Such a comparison of the emulsion data with the results pertaining to interactions of the type $\pi^+ + \mathrm{Xe} \to (N_{ch} \geq 8)$ at 2.34 GeV/c is shown in Fig. 2. The histograms are normalized to each other. It is seen that the presented distributions coincide within the limits of the experimental errors. The corresponding χ^2-criterion estimates yield $0.6 \lesssim \chi^2/n_{DF} \lesssim 1.1$, where $n_{DF} = 8$ is the number of degrees of freedom. Thus, comparison of the angular distributions obtained by us for protons with $E_p \gtrsim 30$ MeV emitted in $\pi^+ + \mathrm{Xe}$ collisions with $N_{ch} \gtrsim 8$ at 2.34 GeV/c with the analogous distributions of the protons emitted in collisions of protons and α particles with heavy emulsion nuclei[7] confirms the conclusion, made also by others,[7] that no irregularities that can possibly be due to shock-wave effects appear in the angular distributions of the secondary protons. It should also be noted that one of the main conditions for shock-wave production is satisfied both in $\pi^+ + \mathrm{Xe}$ interactions at 2.34 GeV/c and in collisions of protons and α particles with heavy emulsion nuclei and with lead at 70 and 17 GeV/c, respectively, since the dimensions of the considered target nuclei greatly exceed (by five times and more) the characteristic mean free path of the particles in nuclear matter. A negative conclusion concerning the shock-wave hypothesis for inelastic collisions of light relativistic nuclei with nuclei is based also on analysis of two-particle correlation functions.[8]

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